



Pentagon Pouring Funds Into a Host of Land and Sea Robots

Articles / Security & Defense

Date: Sep 06, 2003 - 01:30 PM

World events and the military seem to have rendered moot the first of three Rules of Robotics laid down in Isaac Asimov's sci-fi classic I, Robot, namely "A robot must never harm a human being, or through inaction, allow a human being to come to harm."

by Ed Moser



The mountains of broken steel, shattered concrete and superheated rubble left at the World Trade Towers site in the aftermath of the events of September 11, 2001, made it impossible for human rescuers to sift through the ruins in search of bodies and possible survivors. So officials at the site turned to mechanical alternatives - a collection of 17 treaded, basketball-sized machines. They had been developed through the Defense Department's five-year, \$50 million Tactical Mobile Robots (TMR) Program. Over 11 days the robots crawled about the tiny, hellish voids of Ground Zero, and discovered seven bodies. At the same time, another group of three small robots from the University of South Florida clambered over the same terrain. They pointed cameras to distinguish splotches of blood from the gray dust that smothered the debris, and carried microphones to listen for cries for help.

By the following summer, variants of the mechanical rescuers were helping wreak revenge on the collaborators of the 9/11 attacks. The Pentagon had asked iRobot, a MIT spin-off, to retool its Packbot robot for military duty. In one month of service in Afghanistan, the 42-pound, rubber-treaded robots, with Pentium 3 processor brains, assisted in clearing out three buildings, three bunkers, and two-dozen caves. Wide-angle and zoom cameras perched above the squat bodies of the robots enabled soldiers to safely inspect the interiors of buildings in real time. Engineers rigged a network of repeaters to let the \$40,000 contrivances radio back signals from within deep caverns. Global Positioning Satellite (GPS) technology and digital compasses kept the Packbots properly oriented.



Courtesy US Army

After Afghanistan came Iraq, and further successes by land robots and air-borne robot drones. “Robots,” noted the National Academy of Sciences (NAS) in a 2002 report on Army unmanned vehicles, “are fearless and tireless. They do repetitive tasks with speed and precision.”

The Pentagon is now pouring money into “bots,” making military robotics a new growth industry. For fiscal years 2004-2009, the Army is allocating \$500 million to unmanned ground platforms. On a similar note, the Defense Advanced Research Projects Agency (DARPA) is bankrolling over 40 robot-related projects in universities and in private firms.

Robots for the Ground Forces

The military’s plans for land-based robots are extremely ambitious. If put into practice over the next two decades, they would revolutionize the current array of ground weapons, replacing today’s Abram’s tanks and Bradley Fighting Vehicles with swarms of unmanned, autonomous vehicles bristling with missiles and long-range guns, and sewn together with multi-frequency wireless networks. Some critics are skeptical that the proposed deployment time frame to supplement or supplant mechanized ground troops with ground-based mobile robots is sufficient to overcome the daunting technical hurdles associated with the endeavor. But even if that heady vision remains unrealized, robots will likely become a major component of the armed forces’ standard land arsenal by 2010.

The blueprint for the Army’s transformation is its Future Combat System (FCS). Under the FCS, three major groups of robots are envisioned for the wars of the 21st century: a portable reconnaissance robot, a medium-sized transport and recon vehicle, and a large fighting platform. Their roles would be to search out and identify enemy forces and call in strikes from unmanned, autonomous land vehicles and pilotless aircraft. DARPA and the Army have selected United Defense, the Manned Ground Vehicle design team of Boeing and Science Applications International Corporation (SAIC), and General Dynamics Land Systems, as the major FCS contractors for the construction of eight different land vehicles.

The FCS is in its early design stages, and could undergo significant changes. An Army task force has reported that it may be 2025 before fully autonomous ground vehicles are fielded.

Small Unmanned Ground Vehicles

The first Future Combat System vehicle type, the Small Unmanned Ground Vehicle (SUGV), will be outfitted with sensors for reconnaissance. The 30-pound SUGV is

envisioned to be light enough for a single soldier to transport, and nimble enough to climb up stairs and move through rubble. SUGVs could also be equipped with communication sensors and grenades. They will be cheap enough, about \$30,000 each, for the military to procure lots of them. One problem to address is that current versions break down frequently, particularly in inclement weather.

SUGVs will be used largely for tactical surveillance, sometimes in tandem with airborne vehicles. The Packbots deployed in Afghanistan are being outfitted with lenses to detect land mines. Biochemical sensors could detect biological or chemical agents. Upon recognizing a threat, the UGV will be able to call in strikes from unmanned and piloted aircraft. The small robots will be outfitted with a variety of frequencies, for reliable transmission under varying conditions, according to National Defense magazine. In urban warfare situations, low radio frequencies will permit sending messages inside buildings. In open terrain, higher frequencies could be switched on.

Another SUGV-type variant under development is the DARPA-funded Raptor (Robotic Autonomous Perception Technology for Off Road), a project of SAIC. Raptor is a dune buggy-like vehicle with intelligent navigation software that sports both passive and active sensors. It is a so-called “marsupial” system - marsupial as in “kangaroo.” Raptor will act as a robot mothership commanding an attached group of roving robots. In one combat scenario, Raptor would be airdropped into enemy territory, where the mothership would release its family of small robots. These smaller bots would deploy like a squad of human commandos, traversing the terrain using night vision lenses and laser radar to accurately map out surroundings, according to National Defense. They would send collected intelligence to the mothership for assembly and transmission back to base.

Engineers at Draper Laboratory, a MIT spin-off in Cambridge, Massachusetts, are working on military robots even smaller than the Raptor’s swarm. These “throwbots” are tossable robots the size and shape of a grapefruit that a G.I. could hurl into a building suspected of harboring hostile forces. Once inside, the diminutive robot will rove about on spiked wheels, transmitting video from its embedded camera. A soldier monitoring the video images would navigate the throwbot through radio controls.



Courtesy Draper Laboratory

Unmanned Ground Vehicles

The second FCS vehicle type, the Mule Unmanned Ground Vehicle (UGV), is projected to be medium-sized, weighing two tons or more. It will literally “take the

load off of" individual soldiers by transporting supplies and gear, according to John Pike of Global Security. The Army hopes it can get UGVs up and running in three years.

One Mule variant under development, the Robotic Infantry Support System, will provide water purification, battery recharging, a medical station, and top-level sensor and communications platforms. Similarly, the team of Lockheed Martin, BAE Systems, and Sandia National Labs are building a 1,500-pound vehicle that might fit the parameters of the Mule UGV.

UGV development projects are not limited to Mules alone. DARPA is funding a number teams to develop different types of Unmanned Ground Combat Vehicles (UGCVs) that are expected to be able to range up to 300 miles. The \$5.5 million Spinner initiative provides one example. Spinner is a six-wheeled, five-ton unmanned prototype built by Boeing and PEI Electronics of Huntsville. The National Robotics Engineering Consortium (NREC) of Carnegie Mellon University is coordinating the development of the all-terrain, crash-resistant vehicle, according to project chief John Bares.



The Spinner's six independently suspended wheels, each with its own high-torque, liquid-cooled electric motor, enable it to perform its resupply or recon missions, "including the ability to operate while it's inverted," noted Bares. If its flips over, the Spinner can right itself by reorienting its wheels 180 degrees. Ireland-based Timoney Technology designed the unique traction system. PEI Electronics formulated the lithium-ion power pack supported by a diesel-fuel turbine engine.

Armed Reconnaissance Vehicles

Armed Reconnaissance Vehicles (ARV), which can act as weapons platforms, will be the most expensive of the three Future Combat System robotic land vehicle types. One five-ton ARV being developed by General Dynamics could contain 30-mm guns, as well as Hellfire missiles. The ARV might operate autonomously or be directed by a soldier-controller. A reconnaissance version of the ARV may also be produced.

More prosaic is the CyberGuard robot, manufactured by Virginia-based Cybermation. CyberGuard randomly patrols warehouses for private companies. The Pentagon wants to procure and arm CyberGuard with pepper-spray-like weapons.

Navy Efforts

Although the Army dominates the unmanned land vehicle arena, the Navy is also

moving forward on underwater, shoreline, and ground robots.

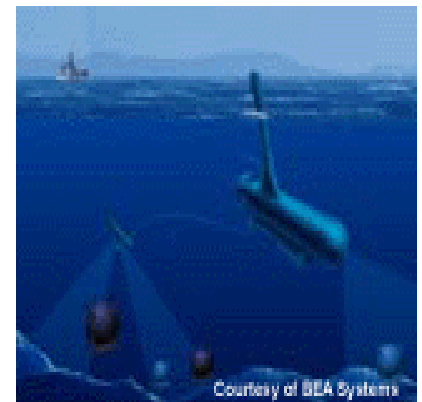
Long in development, the Robart program of the Navy's SPAWAR (Space and Naval Warfare) initiative has progressed from a single, watch guard-style robot that could detect intruders, to one that can assess a situation, and finally on to a mechanized weapon that can fire back at interlopers. The latest version, the Robart III, is equipped with a pneumatic dart gun that can fire six rubber bullets or tranquilizer darts within ten seconds, according to SPAWAR.



Robart possesses a unique firing mechanism that bonds the camera and drive control to the gun to ensure the robot targets where the weapon is pointed. Few intruders will get past Robart's complex of sensors – a microwave motion detector, an infrared proximity sensor, sonar transducers, and a surveillance camera. Navy researchers are attempting to turn the single Robart machine into a proactive group of robots. In the master/slave network that is envisioned, companion bots would accompany Robart into a war-torn site to serve as lookouts and data-relay points.

Another Navy effort, the \$50 million Spartan project, is an Advanced Concept Technology program designed to develop four prototypes of a surface platform geared for operation in littoral areas. The 10-foot-long, operator-controlled vehicles will move at 14 mph conducting surveillance. It will also carry a ton-and-a-half of payload to execute mine clearing. The Spartan's contractors – Northrup Grumman, Raytheon, and Integrated Maritime Platforms International – plan to deploy the Spartan UGV by 2007.

The Navy hopes to conduct mine sweeping operations underwater as well. Operating over the horizon from US naval vessels, the Remote Minehunting System (RMS) will detect and record mines that are moored or on the sea bottom. Anti-submarine warfare is another potential mission. The contractors for the \$130 million RMS program are Lockheed Martin, Raytheon, Harris, Areté, and BAE.



Another intriguing project is Draper Laboratory's "robotic tuna", or VCUUV (Vorticity Control Unmanned Undersea Vehicle). With the appearance and maneuverability of a yellowfin tuna, the VCUUV will be able to swim underwater at depths of 100 feet for up to three hours.

Technical Challenges

Much hard research remains if robots are to fulfill the considerable demands of the military branches. According to Army Lieutenant Colonel (retired) John Blitch, who led the robot search effort at Ground Zero, and is widely considered the godfather of the military's land robot programs, future military robotic devices will have to be able to comply with his Five Imperatives:

"A Tactical Mobile Robot must be able to get back on its feet when it has fallen. It must be able to recover from communication loss. It must know where it is. It must be tamperproof. And it must be able to maneuver around complex obstacles."

National Academy of Sciences would add another imperative to the Blitch five – integration, particularly data integration. The 2002 NAS report on Army unmanned vehicles concludes "the greatest technical challenge for fielding UGVs is likely to be technology integration," including the integration of the many sensors a robot could carry.

Autonomous Operation

Robots have progressed from radio-controlled devices always in sight of their human handlers to tele-assisted machines that can transmit data from afar, with occasional adjustment from their handlers. A key goal now is construction of robots that can perform whole missions independent of human intervention.

Artificial intelligence will play a critical role in autonomous operation. Research in this area is moving along on a number of fronts. For example, SAIC engineers are designing software in which a robot's arrays of sensors upload incoming data to other sensors to generate a set of directives. The processed information is then passed on to more sophisticated software that decides on a course of action for the robot.

DARPA's Information Processing Technology Office is planning research on cognitive software systems that will attempt to mimic the human mind in making sense of changing, unpredictable situations. Drawing on the work of psychologists and philosophers, such systems, the Agency hopes, will set priorities, learn from experiences, adjust to surprises, plan for the future, and make use of context to determine the optimal response. Also working in this field is the Navy Center for Applied Research in AI, which stresses the incorporation of continuous learning and constantly evolving behaviors in its robotic software.

Turning to the Natural World

Perhaps the most surprising area of research into autonomous operation involves the natural world. To improve the mobility and intelligence of its machines, the

military is applying lessons culled from insects and other animals. Again, DARPA is in the fore, through its Defense Sciences Office's three-year Controlled Biological and Biomimetic Systems program. The Office of Naval Research is another sponsor.

Researchers hope to use creatures directly, or adapt their behaviors in robots. Moths might be trained to detect chemical weapons, for example. Beetles might lead to improved sensors, as the bugs can sense a fire from 40 miles away with their natural smoke detection mechanisms.

Scientists are also trying to apply to robots the manner in which animals move through challenging terrain. Lobsters, Northeastern University researchers have found, keep their balance in pounding surf by, in effect, skiing with their legs. Geckos walk across ceilings by peeling and sticking back on their feet. McGill University's Center for Intelligent Machines has concluded that, for stability at least, four or more legs are better than two. A multiple of mechanical legs might also beat treads when it comes to getting up steep hillsides. NASA's Jet Propulsion Laboratory is developing five-jointed mechanical snakes and tiny robotic worms that could slither through ruined buildings.

Just the Beginning

The emphasis on homeland security, causality reduction during combat and cost savings has pushed robots and robotic research onto the fast track for government spending. The expected result is that future military forces will employ a variety of robotic devices for reconnaissance and surveillance, logistics and support, and offensive operations. Given the Pentagon's vast, well-funded and long-term robot program, many more discoveries, applications, and business opportunities will result from the application of robotics in the service of military operations.

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This article comes from Robotics Trends

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